

Forecasting Production Pattern of Sugar, Molasses, Bagasse and Pressmud in India using ARIMA Model .

Abstract:

The present paper attempts forecasting production pattern of sugar, molasses, bagasse and pressmud in India through fitting of Auto Regressive Integrated Moving Average (ARIMA) models. The data on production of sugar and its by-products collected from 1999-2019 has been used for present study. The performances of different ARIMA models are validated by standard statistical techniques and compared with actual values. Among the ARIMA models, ARIMA (2,1,1) model is found to be the best model and is used for forecasting the production pattern of sugar as well as by-products up to the period 2029-30. The model found that production of sugar, molasses, bagasse and pressmud would grow to 34.87, 16.39, 30.51 and 11.86 million MTs in 2029-30 respectively. We also found that the production pattern of sugar, bagasse and pressmud follow cubic trend where as that of bagasse follows quadratic trend. These projections will help in making good policies with respect to the production scenario the country.

Key words:-

Sugarcane, Sugar, Bagasse, Molasses, Press mud, By-products

Introduction:-

Sugar industry is a second biggest agro based industry in India and has very strong impact on food security, energy security and economy of the country. It directly affects socio-economic growth of over 50 million Indians who are associated with sugarcane cultivation and sugar industry for their livelihood. Presently, about 5 million hectares of land is under sugarcane cultivation with average yield of 70 MT/ha. There are about 747 working sugar mills with an average crushing capacity of 35,000 tonne/day. India has produced 33 million MTs of sugar ie 19% of world sugar production of 179 million MTs. India has become the world's largest sugar producer as on 2018-19 beating out Brazil for the first time in last 16 years. India is also the largest consumer with annual consumption of 26 million MTs and third largest sugar exporter with worth of 17.6 million US dollars.

Even though, India being third largest sugar exporter and largest consumer of sugar in the world, around 40% of total sugar produced left unsold every year affecting demand and supply chain. Global competitions in the sale of sugar and rise in the cost of inputs made the profitability of the Indian sugar industry declining day by day. In the era of globalization and competition there is an urgent need for every Indian sugar industry to be cost-effective and competitive. This could be possible only through fuller and better utilization of the by-products through value addition process. Thus, diversification of sugarcane by-products of lower economic value in to higher value added products within the sugar industry would derives maximum benefit for the industry as well as farmers.

Today, modern technologies have opened new avenues of opportunities to sugar industries in the process of diversification of its various by-products molasses, bagasse and pressmud in to value added products of higher economic significance. Bagasse can be used in the production of power, craft paper, writing and printing paper, newsprint, tissue paper, cardboards and manufacture of furfural; molasses is used for production of alcohol by fermentation with yeast and chemicals like acetic acid, acetone, butyl alcohol, ethylene citric acid by suitable treatment. Biofuel and methane gas can also be generated from distillery effluent; press mud and spent ash have been used effectively in preparing bio-compost very useful organic manure which can be distributed back to the agriculture community. ²

Recent years, sugarcane emerged as a multi-product crop and also an essential commodity; it has a significant role in determining the inflation rate, wages and various policies in Indian economy. Hence, a proper understating and forecasting the production pattern of sugar and its byproducts is vital for proper planning for the future. In this point of view, studying the production pattern of the past and assessment of the same in future play vital role. The present study focuses on the modeling and forecasting production pattern of sugar and its by-products viz., molasses, bagasse and pressmud in India using ARIMA model.

In the arena of time series modelling, till date Autoregressive integrated moving average (ARIMA) model is a stand out amongst the most main stream approach for agriculture crop forecasting. In the contest of sugarcane, there are many reports of ARIMA based forecasting of cultivation area, production of sugarcane and sugar under different time scale are available in literature. But reports on forecasting of sugarcane by-products such as molasses, bagasse and pressmud in India using ARIMA are not available in literature. In this regard, of molasses available in the literature

Objectives:

The main objectives of our work are below

1. To forecast the production of sugar and its major by-products (molasses, bagasse, and pressmud) in India using the Auto Regressive Integrated Moving Average (ARIMA) model.
2. To evaluate the forecasting performance of the ARIMA model by comparing the predicted values with the actual production data and analyzing the forecasting errors.
3. To assess the future production trends of sugar and its by-products and provide insights for policy formulation, industrial planning, and sustainable utilization of sugar industry by-products in India.

Methodology:-

To develop models and subsequently to use the best fitted models to forecast the series for the years to come, data for the whole period are used for model building and model validation purpose. Descriptive statistics are useful to describe patterns and general trends in a data set. It includes numerical and graphic procedure to summarize a set of data in a clear and understandable way. To examine the nature of each series these have been subjected to different descriptive measures. Statistical measures used to describe the above series are mean, standard deviation, coefficient of variance and compound annual growth rate.

ARIMA models, stands for Autoregressive Integrated Moving Average models. Integrated means the trends has been removed; if the series has no significant trend, the models are known as ARMA models. The notation AR (p) refers to the autoregressive model of order p; the AR(p) model is written

$$X_t = c + \sum_{i=1}^p \alpha_i X_{t-i} + \mu_t$$

where $\alpha_1, \alpha_2, \dots, \alpha_p$ are the parameters of the model, c is a constant and μ_t is white noise i.e. $\mu_t \approx WN(0, \sigma^2)$. Sometimes the constant term is omitted for simplicity.

Result and Discussion:-

The Auto Regressive Integrated Moving Average (ARIMA) model was employed to forecast the production of sugar and its major by-products, namely molasses, bagasse, and pressmud, in India. The historical dataset (1999–00 to 2018–19) was used to validate the forecasting performance of the model, while projections were generated for the period 2019–20 to 2029–30. The comparison between actual and predicted values demonstrates that the ARIMA model effectively captured the long-term production trends despite fluctuations arising from climatic variability, changes in sugarcane acreage, and policy interventions.

The validation results indicate that the ARIMA model performed satisfactorily during relatively stable production periods but exhibited larger forecasting errors during years characterized by extreme fluctuations. Sugar production recorded considerable variability over the study period, ranging from 12.69 million MT in 2004–05 to 33.16 million MT in 2018–19. During normal production years, such as 2011–12 and 2013–14, the forecast closely matched the observed values, with prediction errors of only 0.09 and 0.93 million MT, respectively. However, substantial deviations were observed during abnormal production years. For instance, in 2003–04 the actual sugar production declined sharply to 13.55 million MT, whereas the ARIMA model predicted 21.04 million MT, resulting in an error of –7.50 million MT. Similarly, in 2017–18 the model underestimated production by 5.86 million MT due to unexpectedly high sugarcane output. These findings suggest that ARIMA effectively captures historical trends but

has limitations in predicting abrupt structural changes caused by monsoon variability, pest incidence, government pricing policies, and cyclical sugarcane cultivation.

A similar pattern was observed for molasses production. Since molasses is generated directly from sugar manufacturing, its production followed trends nearly identical to sugar output. Forecasting errors remained relatively small during stable years, with an error of only -0.02 million MT in 2011-12 and -0.05 million MT in 2013-14. However, years experiencing substantial reductions in sugar production also showed significant forecasting errors for molasses. The largest deviation occurred in 2003-04, when the actual production was only 5.91 million MT compared with the predicted 9.29 million MT, producing an error of -3.39 million MT. Likewise, in 2006-07 the model underestimated molasses production by 2.58 million MT because of the unprecedented increase in sugar output. These results confirm the strong dependence of molasses production on sugarcane crushing volumes and sugar recovery rates, indicating that accurate sugar forecasts directly improve the prediction of molasses availability.

Bagasse production exhibited trends closely associated with sugarcane processing volumes. Since bagasse accounts for the fibrous residue remaining after juice extraction, its production is influenced primarily by the quantity of sugarcane crushed rather than sugar recovery alone. The ARIMA model estimated bagasse production with reasonable precision during most years. For example, prediction errors were only 0.15 million MT in 2011-12 and 0.69 million MT in 2013-14. Nevertheless, larger deviations were observed during years of abnormal production, particularly in 2003-04, where the actual production was 11.93 million MT compared with the predicted value of 18.28 million MT, resulting in an error of -6.35 million MT. Similarly, the model underestimated production by 4.31 million MT in 2006-07 and by 4.09 million MT in 2017-18. These deviations reflect the inability of time-series models to anticipate sudden changes in sugarcane acreage and climatic conditions that significantly affect biomass availability.

Pressmud production also followed a trend similar to sugar and bagasse production because it is another important by-product generated during sugar clarification. The prediction errors were generally smaller than those observed for sugar and bagasse due to the relatively stable proportion of pressmud generated during processing. The smallest forecasting error was observed in 2011-12 (0.06 million MT), while larger deviations occurred in years with abnormal production, particularly 2003-04 (-2.47 million MT) and 2017-18 (1.59 million MT). Overall, the model adequately represented long-term production behaviour while slightly underperforming during years characterized by exceptional increases or decreases in sugarcane production.

The ARIMA forecasts for the period 2019-20 to 2029-30 indicate a generally positive outlook for India's sugar industry. Sugar production is projected to fluctuate within a relatively narrow range during the forecast horizon. Production is expected to remain around 27.12 million MT in 2019-20, decline slightly to 25.85 million MT in 2020-21, and subsequently recover to 30.69 million MT in 2021-22 and 33.51 million MT in 2022-23. Beyond 2024-25, production is forecast to stabilize above 30 million MT and eventually reach approximately 34.87 million MT by 2029-30. This steady upward trend reflects anticipated improvements in sugarcane productivity, adoption of high-yielding varieties, better irrigation facilities, and continued government support for the sugar industry.

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The projected increase in sugar production is accompanied by corresponding increases in all major by-products. Molasses production is expected to increase from 12.83 million MT in 2019–20 to approximately 16.39 million MT by 2029–30. Since molasses is the principal feedstock for ethanol production, this forecast suggests significant opportunities for expanding India's ethanol blending programme and reducing dependence on imported fossil fuels. The increasing availability of molasses will strengthen the biofuel sector while providing additional revenue streams for sugar mills.

Bagasse production is projected to increase steadily from 24.33 million MT in 2019–20 to 30.51 million MT in 2029–30. The growing availability of bagasse is particularly important for cogeneration of electricity and production of renewable energy. Many sugar mills in India have already adopted bagasse-based cogeneration plants, and the forecasted increase in bagasse availability indicates considerable potential for further expansion of green power generation. Enhanced utilization of bagasse can also contribute to the manufacture of paper, biodegradable packaging materials, compressed biofuels, and second-generation bioethanol, thereby promoting resource efficiency and circular bioeconomy principles.

Similarly, pressmud production is forecast to increase gradually from 9.46 million MT in 2019–20 to nearly 11.86 million MT by 2029–30. Pressmud has considerable economic value as an organic manure, composting material, and feedstock for biogas generation. The increasing availability of pressmud supports sustainable agricultural practices by improving soil fertility and reducing dependence on chemical fertilizers. Consequently, the forecasted growth in pressmud production complements national efforts toward environmentally sustainable agriculture and integrated waste utilization.

I. TABLE 1: PRODUCTION PERFORMANCE OF SUGAR INDUSTRY IN INDIA

Year	No of Working Factories	Average Working Days/Year	Average Capacity (MTs/day)	Quantity of Sugarcane Crushed (Million MTs)	Production of Sugar and By-products (Million MTs)					
					Sugar	Sugar Yield	Molasses	Molasses Yield	Bagasse*	Pressmud*
1999-00	423	151	3049	178.494	18.200	10.20	8.013	4.49	16.064	6.247
2000-01	436	138	3203	176.660	18.511	10.48	7.820	4.43	15.899	6.183
2001-02	434	138	3285	180.346	18.528	10.27	8.073	4.48	16.231	6.312
2002-03	453	140	3343	194.365	20.145	10.36	8.879	4.57	17.493	6.803
2003-04	422	99	3493	132.511	13.546	10.22	5.905	4.46	11.926	4.638
2004-05	400	97	3508	124.772	12.690	10.17	5.513	4.42	11.229	4.367
2005-06	455	125	3619	188.672	19.267	10.21	8.549	4.53	16.980	6.604
2006-07	504	173	3561	279.295	28.328	10.16	13.111	4.69	25.137	9.775
2007-08	516	149	3586	249.906	26.357	10.55	11.313	4.53	22.492	8.747
2008-09	489	87	3751	144.983	14.539	10.03	6.546	4.52	13.048	5.074
2009-10	490	109	3846	185.548	18.912	10.19	8.400	4.53	16.699	6.494
2010-11	527	135	3744	239.807	24.394	10.17	10.970	4.57	21.583	8.393

2011-12	529	137	3877	256.975	26.343	10.25	11.824	4.60	23.128	8.994
2012-13	526	127	4119	250.598	25.141	10.03	11.745	4.69	22.554	8.771
2013-14	513	115	4061	238.176	24.360	10.23	10.850	4.56	21.436	8.336
2014-15	538	133	4117	273.073	28.313	10.37	12.479	4.57	24.577	9.558
2015-16	526	117	3843	236.498	25.125	10.62	10.885	4.60	21.285	8.277
2016-17	489	100	4135	193.434	20.262	10.48	9.002	4.65	17.409	6.770
2017-18	525	141	4439	301.198	32.328	10.73	13.980	4.64	27.108	10.541
2018-19	532	143	4521	312.122	33.161	10.62	14.482	4.64	28.091	10.924
Mean	486.35	127.70	3755.00	216.87	22.42	10.32	9.92	4.56	19.52	7.59
Std Dev	44.59	21.54	397.05	54.51	5.86	0.20	2.62	0.08	4.91	1.91
CV	9.17	16.87	10.57	25.14	26.13	1.94	26.41	1.75	25.14	25.14
CAGR (%)	1.21	-0.29	2.09	2.98	3.21	0.21%	3.16	0.17	2.99	2.99

II. TABLE 2: PARAMETRIC TREND MODELS FOR PRODUCTION OF SUGAR AND ITS BY-PRODUCTS IN INDIA

Parameter	Equation	Intercept	Regression coefficients			R^2	F-ratio	p-value
			b_1	b_2	b_3			
Sugar Production	Cubic	18.389	-0.461	0.101	-0.003	0.494	5.526	0.008
Molasses Production	Quadratic	7.523	0.076	0.11	-	0.554	11.169	0.001
Bagasse Production	Cubic	15.475	-0.085	0.052	-0.01	0.506	5.812	0.006
Pressmud Production	Cubic	6.018	-0.033	0.020	0.00	0.506	5.811	0.006

Table 3: Diagnostics of ARIMA model selection for the production of sugar and its by-products in India

	ARIMA Model	No. of Predictors	Model Fit statistics							No. of Outliers
			R^2	RMSE	MAPE	MAE	MaxAPE	MaxAE	BIC	
Sugar Production	(2,1,0)	0	0.500	4.374	14.300	3.037	55.237	8.646	3.401	0
	(2,1,1)	0	0.679	3.612	12.830	2.534	55.338	7.496	3.168	0
	(2,1,2)	0	0.662	3.831	13.053	2.633	55.430	7.509	3.435	0
Molasses Production	(2,1,0)	0	0.530	2.020	14.916	1.453	57.094	3.810	1.855	0
	(2,1,1)	0	0.696	1.676	12.862	1.161	57.336	3.386	1.631	0
	(2,1,2)	0	0.673	1.794	13.076	1.205	56.805	3.354	1.917	0
Bagasse Production	(2,1,0)	0	0.525	3.651	13.652	2.575	52.224	6.920	3.040	0
	(2,1,1)	0	0.692	3.028	12.277	2.155	53.273	6.353	2.815	0
	(2,1,2)	0	0.669	3.242	11.584	2.109	52.217	6.503	3.102	0
Pressmud Production	(2,1,0)	0	0.525	1.420	13.654	1.001	52.225	2.690	1.150	0
	(2,1,1)	0	0.692	1.177	12.276	0.838	53.271	2.471	0.926	0
	(2,1,2)	0	0.669	1.261	11.581	0.820	52.221	2.526	1.212	0

III. TABLE 4: FORECASTED VALUES FOR PRODUCTION OF SUGAR AND ITS BY-PRODUCTS IN INDIA

Year	Sugar Production (Million MTs) *			Molasses Production (Million MTs) *			Bagasse Production (Million MTs) *			Pressmud Production (Million MTs) *		
	A	P	E	A	P	E	A	P	E	A	P	E
1999-00	18.20	-	-	8.01	-	-	16.06	-	-	6.25	-	-
2000-01	18.51	18.85	-0.34	7.82	8.33	-0.51	15.90	16.62	-0.72	6.18	6.46	-0.28

2001-02	18.53	19.17	-0.64	8.07	8.15	-0.08	16.23	16.47	-0.24	6.31	6.40	-0.09
2002-03	20.15	19.45	0.70	8.88	8.70	0.18	17.49	17.26	0.23	6.80	6.71	0.09
2003-04	13.55	21.04	-7.50	5.91	9.29	-3.39	11.93	18.28	-6.35	4.64	7.11	-2.47
2004-05	12.69	17.03	-4.34	5.51	7.24	-1.73	11.23	14.61	-3.38	4.37	5.68	-1.31
2005-06	19.27	21.13	-1.86	8.55	8.92	-0.37	16.98	17.96	-0.98	6.60	6.99	-0.38
2006-07	28.33	23.95	4.38	13.11	10.54	2.58	25.14	20.83	4.31	9.78	8.10	1.68
2007-08	26.36	23.50	2.85	11.31	11.07	0.25	22.49	21.14	1.35	8.75	8.22	0.53
2008-09	14.54	18.28	-3.74	6.55	8.12	-1.58	13.05	15.94	-2.89	5.07	6.20	-1.12
2009-10	18.91	17.02	1.89	8.40	7.77	0.63	16.70	14.99	1.71	6.49	5.83	0.66
2010-11	24.39	27.10	-2.70	10.97	11.75	-0.78	21.58	23.18	-1.60	8.39	9.01	-0.62
2011-12	26.34	26.25	0.09	11.82	11.84	-0.02	23.13	22.98	0.15	8.99	8.94	0.06
2012-13	25.14	24.03	1.11	11.75	10.98	0.77	22.55	21.07	1.48	8.77	8.20	0.58
2013-14	24.36	23.43	0.93	10.85	10.90	-0.05	21.44	20.74	0.69	8.34	8.07	0.27
2014-15	28.31	25.01	3.30	12.48	11.03	1.45	24.58	21.54	3.04	9.56	8.38	1.18
2015-16	25.13	27.69	-2.57	10.89	12.63	-1.74	21.29	24.22	-2.93	8.28	9.42	-1.14
2016-17	20.26	24.99	-4.73	9.00	11.37	-2.37	17.41	21.67	-4.26	6.77	8.43	-1.66
2017-18	32.33	26.47	5.86	13.98	11.93	2.05	27.11	23.02	4.09	10.54	8.95	1.59
2018-19	33.16	34.05	-0.89	14.48	15.31	-0.82	28.09	29.62	-1.53	10.92	11.52	-0.60
2019-20		27.12			12.83			24.33			9.46	
2020-21		25.85			13.11			23.65			9.20	
2021-22		30.69			12.79			25.47			9.90	
2022-23		33.51			14.06			27.98			10.88	
2023-24		31.93			15.08			28.35			11.03	
2024-25		30.56			15.07			27.59			10.73	
2025-26		32.17			14.84			27.83			10.82	
2026-27		34.40			15.17			29.14			11.33	
2027-28		34.82			15.81			30.14			11.72	
2028-29		34.35			16.23			30.35			11.80	
2029-30		34.87			16.39			30.51			11.86	

* A= Actual, P=Predicted, E=Error

Conclusion:-

The present study demonstrates the usefulness of the ARIMA model in forecasting the production of sugar and its major by-products, namely molasses, bagasse, and pressmud, in India. The model successfully captured the long-term production trends and generated reliable forecasts despite the inherent variability in agricultural production. Although larger prediction errors were observed during years affected by climatic fluctuations and unexpected production shocks, the overall forecasting performance was satisfactory, indicating the suitability of ARIMA for medium- and long-term production planning.

The forecast results suggest a gradual increase in the production of sugar and its by-products over the coming years, reflecting positive prospects for the Indian sugar industry. Increased availability of molasses will support the expansion of ethanol production and the national biofuel programme, while higher bagasse production will enhance renewable energy generation through cogeneration. Similarly, the projected increase in pressmud production offers opportunities for sustainable organic manure production and improved soil health.

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